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ABSTRACT

The Harvard-Smithsonian Center for Astrophysics (CfA) is a joint collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. The CfA's research mission is the study of the origin, evolution, and ultimate fate of the universe. This 16-page booklet profiles women in the physical sciences or related fields; it is an effort to encourage young women to pursue science and science-related careers, particularly in astronomy and astrophysics. The profiles featured give readers an idea of the types of jobs found in a typical, nonprofit, scientific research institute. The booklet also includes tips on how to prepare for a career in astronomy or astrophysics, with advice on course work, choosing colleges, and finding mentors. Women profiled are: Patricia Brennan, department administrator; Andrea Dupree, stellar physicist; Barbara Welther, science historian; Donna Coletti, librarian; Kathryn Flanagan, instrument developer; Marquita Jackson-Minot, education specialist; Kimberly Dow, astrophysicist; Alyssa Goodman, astrophysicist; Carolyn Stern Grant, computer specialist; Kate Kirby, astrophysicist; Tania Ruiz, astronomer; and Ursula Marvin, geologist. An appendix contains information on magazines, books, videos, organizations and internship and related programs. Also contains a glossary. (LSR)

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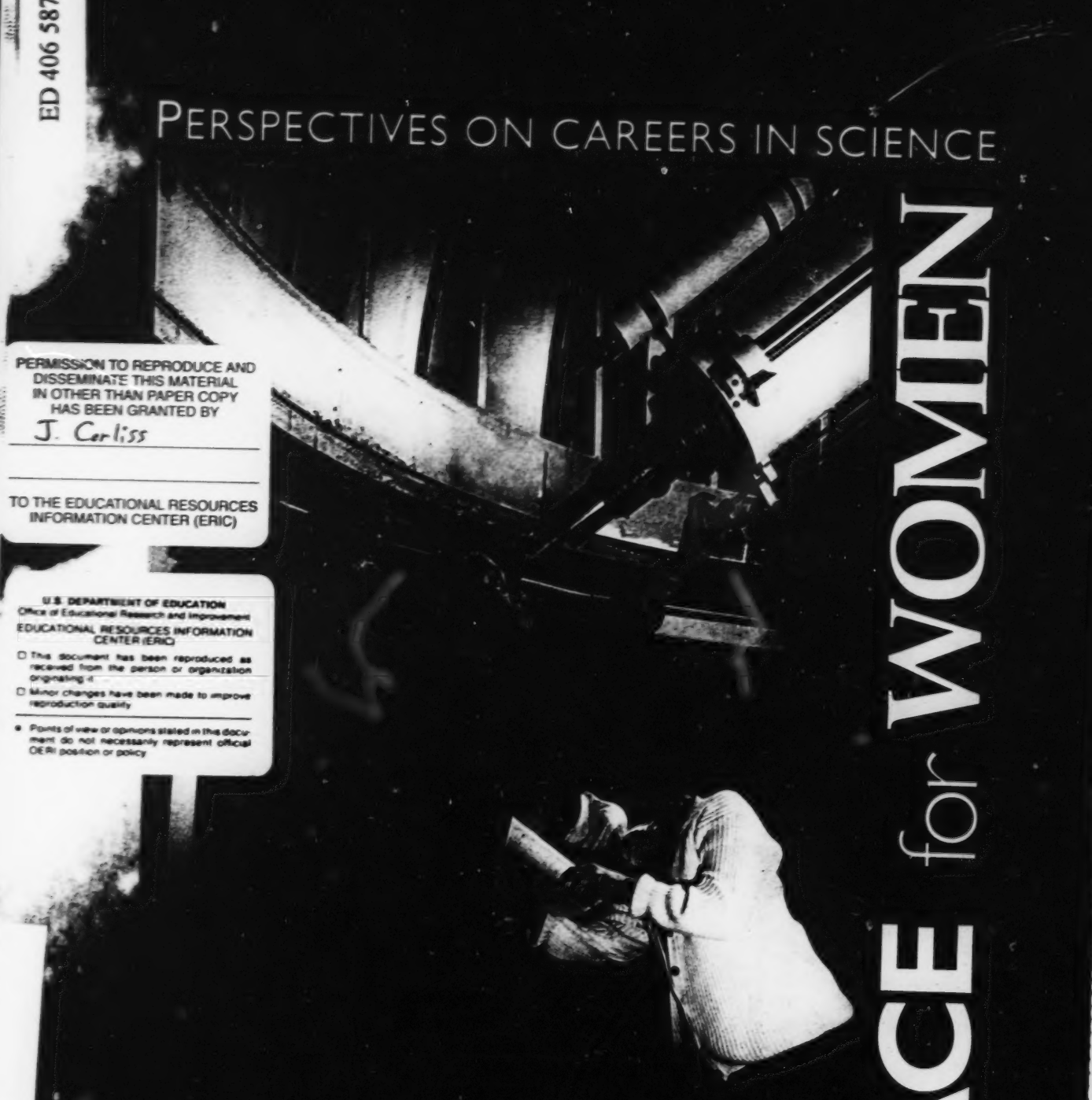
HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS

PERSPECTIVES ON CAREERS IN SCIENCE



SPACE for WOMEN

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What Is the Center for Astrophysics?

Located in Cambridge, Massachusetts, the Harvard-Smithsonian Center for Astrophysics (CfA) is a joint collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. The CfA's research mission is the study of the origin, evolution, and ultimate fate of the universe. More than 200 professional astronomers, supported by some 500 technical, engineering, and administrative staff, pursue a broad program of research, organized into the following seven scientific divisions:

✦ **Atomic and Molecular Physics**: Through laboratory and space experiments, as well as theoretical studies, attempts to describe and understand those atomic and molecular processes determining the nature of celestial bodies and the gas and dust lying between them.

✦ **High Energy Astrophysics**: Observes x rays and gamma rays from hot, energetic objects such as supernovas, black holes, and neutron stars, by using instruments that fly aboard satellites, rockets, and balloons. Scientists in this division also design and test new instruments to detect this radiation.

✦ **Optical and Infrared Astronomy**: Studies objects both within and outside our galaxy, with optical and infrared telescopes on satellites, balloons, and the ground. Research is designed to determine the large-scale structure of the universe, the formation and evolution of stars and galaxies, and the development of planets around stars.

✦ **Planetary Sciences**: Studies the planets, their satellites, and the small bodies of our solar system, including meteors, comets, and asteroids. Scientists create computer simulations of the events and processes that created these bodies from gas and dust in the early solar system. Recovered meteorites and lunar samples are studied for clues to the formation and history of the Earth.

✦ **Radio and Geoastronomy**: Research includes the observation and analysis of radio-emitting astronomical objects, including powerful space masers and massive objects deep in the cores of galaxies. Very Long Baseline Interferometry (VLBI) techniques are used to create high-resolution images of distant celestial bodies and to measure the slow motions of great continental plates on Earth.

✦ **Solar and Stellar Physics**: Studies physical processes on the Sun that relate to its activity and its influence on interplanetary space, especially the Earth. Also studies processes that control the evolution and behavior of stars and their interaction and influence on the interstellar medium. Scientists use spaceborne instruments and robotic telescopes on the ground.

✦ **Theoretical Astrophysics**: Creates and analyzes mathematical models designed to help understand a variety of puzzling astronomical phenomena, such as neutron stars, the behavior of atoms and molecules in interstellar space, the spiral structure of galaxies, the formation of planets in the early solar system, and the creation of the universe.

Science-related departments within the CfA include **Central Engineering**, which designs and builds instruments for space and ground observatories; the **Computation Facility**, which supports the varied computer needs of the research and administrative staff; **Publications/Public Affairs**, which distributes staff-written scientific articles and prepares and organizes written materials, recordings, and lectures for the public on general astronomy topics and CfA research; and **Science Education**, which creates and conducts programs designed to improve instruction of precollege science, including summer workshops and video teleconferences for teachers, and curriculum and computer software development. In addition, scores of administrative staff assist scientists through the following departments: **Controller** (Accounting), **Contracts and Procurement**, **Human Resources**, **Library**, **Purchasing**, and **Travel**.

The CfA also has a **Women's Program Committee** that provides programming for the recruitment, retention, and professional development of women at the CfA. The Committee meets monthly to identify areas in which women are underrepresented, to develop potential solutions for apparent problems, and to create programs of interest to women (and men) at the CfA.

About "Space for Women"

In 1975, a group of women at the Harvard-Smithsonian Center for Astrophysics (CfA) held a conference, "The Earth in the Cosmos: Space for Women," to give young women an idea of what it's like to have a career in the physical sciences or related fields. The speakers included astrophysicists, astronomers, and geologists, as well as computer programmers, educators, science editors, and other women working in science-related careers. The women talked about what they found exciting and fulfilling about their jobs, as well as some of the challenges they faced. Highlights from the symposium were documented in the first "Space for Women" booklet. Two additional conferences were held in 1992 and 1993.

At the time of the first conference, about 40 percent of all working-age women were employed outside the home. Twenty years later, that number surpassed 60 percent, and is projected to reach 80 percent by the year 2000. However, very few working women become scientists or engineers. In the early 70's, only about 6 percent of all scientists and engineers were women. By the mid-1990's, that percentage had risen to 16. Despite that advance, women still have a long way to go before they are equally represented in scientific fields.

This booklet is an effort to encourage young women to pursue science and science-related careers, particularly in astronomy and astrophysics. The profiles featured here are designed to give women an idea of the types of jobs found in a typical, nonprofit, scientific research institute. But the booklet also includes tips about how to prepare for a career in astronomy or astrophysics, with advice on course work, choosing colleges, and finding mentors.

The specialized field of astrophysics, of course, offers a limited number of opportunities for Ph.D.-level scientists. However, women with bachelor's or master's degrees can also find rewarding experiences in science and make significant contributions in research. In fact, there are many other opportunities in science-related careers, as computer specialists, librarians, and administrators, for example. People with degrees in astronomy or physics also work in science museums and planetariums, as teachers, science historians, science writers, or even as congressional lobbyists who promote astronomical and space research.

"The CfA is an exciting place to work because there are always new scientific projects in the works, each with different engineering and administrative challenges. My job is constantly changing and expanding in new directions."

—Patricia Brennan, department administrator

Brennan works in Central Engineering, the department that designs and builds instruments for research aboard satellites, balloons, rockets, and the Space Shuttle. Her responsibilities include recruiting new employees, tracking engineering assignments, accounting, and troubleshooting computer problems. Brennan, who has a degree in psychiatric social work, started at the CfA as a secretary and worked her way up, learning most of her skills on the job. As an antidote to working in a fast-paced, high-tech environment, she and her husband live in an 18th century farmhouse in Maine, where she enjoys spinning and weaving wool scarves and blankets.

Andrea Dupree

[Stellar Physicist]

What fascinates Andrea Dupree about astrophysics is precisely what distinguishes it from many other fields of science—and, in fact, from the daily experiences of most people.

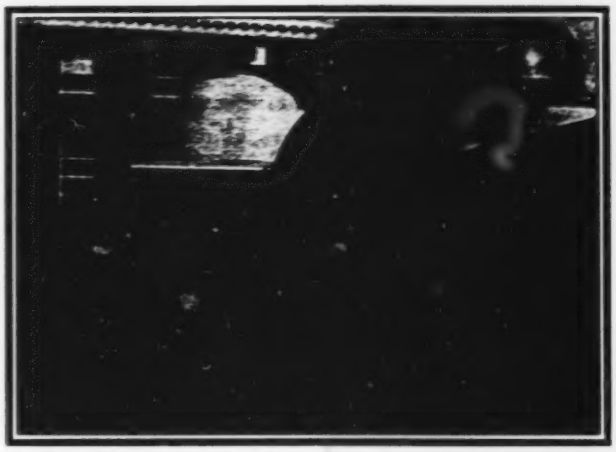
"In everyday life, you have to touch or look at something up close to understand it. In astrophysics, all our subjects are millions of miles away. I'm constantly amazed at how much we can understand just by capturing the very weak light from these very distant objects," says Dupree, a senior astrophysicist in the CfA's Solar and Stellar Physics Division.

Those long-traveling, faint beams of light reveal clues about how stars are born, how they evolve, and how they die—the ultimate goal of Dupree's research. "Stars are the fundamental building blocks of the universe. To understand the universe, you have to understand how stars work," says Dupree, who is an internationally recognized specialist in ultraviolet astronomy.

Her journey toward that achievement began almost by accident, when she took an astronomy course at Wellesley College to fulfill a graduation requirement. Her interest was piqued, and after receiving a BA in astronomy and physics in 1960, she was awarded a prestigious Woodrow Wilson Fellowship—despite a frustrating interview with the fellowship review committee. "They asked me, 'How do we know you'll actually go to graduate school, and not just drop out, get married and have children?' I remember going back to the dorm at Wellesley and carrying on to my friends, I was so upset. No one had ever doubted me before!" says Dupree.

Proving her reviewers wrong, albeit unintentionally, she married *and* went to graduate school, earning her doctorate in astrophysics from Harvard in 1968. She and her husband, Thomas, a professor at MIT, have a son and a daughter.

Dupree did all her postgraduate work at Harvard in Cambridge, a scenario that worked well for her but isn't typical among young scientists, who usually work at several different institutions before settling into a permanent position. "I might have gone farther, faster, if I'd moved around a lot," says Dupree. Nonetheless,



she's achieved an enviable record of accomplishments, including receiving the esteemed Bart Bok Prize in astronomy and being elected president of the American Astronomical Society. And, in 1980, Dupree was appointed an associate director of the CfA, the youngest person and the first woman to hold such a position.

She's also been the principal investigator and team leader for CfA-designed observing programs aboard the Hubble Space Telescope, the International Ultraviolet Explorer satellite, and the Extreme Ultraviolet Explorer satellite. Because ultraviolet radiation is absorbed by the Earth's atmosphere, researchers must rely on satellite-borne telescopes to gather ultraviolet light from celestial objects.

She and colleagues are particularly interested in stars within globular clusters—enormous, spherical collections of stars that share a common origin, yet differ from one another in terms of their mass. Using a special detector on a telescope on Mauna Kea in Hawaii, they found the first evidence of ultra-fast winds that sweep material off the surfaces of old stars—a discovery that helps explain a long-held conjecture that these stars lose mass.

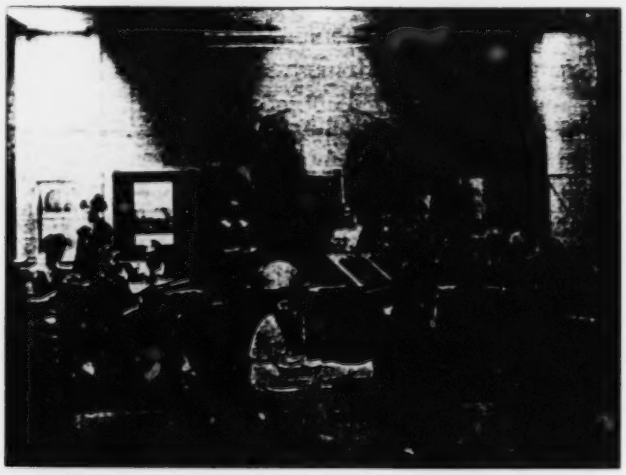
For Dupree, scientific insights may come at any time—even during everyday, household tasks. "I might be in the kitchen making dinner, when all of a sudden, the pieces fall together and you think, 'Wow!'"✦

Why Women?

The rationale for encouraging more women to participate in astronomy is succinctly described in the preamble to the "Baltimore Charter," an outgrowth of the Conference on the Status of Women in Astronomy held in 1992 at the Space Telescope Science Institute in Baltimore, Maryland. The conference defined, argued, and addressed the problems faced by women at the graduate level and beyond. The workshop proceedings, which include the following preamble to the Charter, were published in the booklet, *Women in Astronomy*. (See *Appendix* for additional information.)

We hold fundamental that:

- Women and men are equally capable of doing excellent science
- Diversity contributes to, rather than conflicts with, excellence in science
- Current recruitment, training, evaluation, and award systems often prevent the equal participation of women
- Formal and informal mechanisms that are effectively discriminatory are unlikely to change by themselves. Both thought and action are necessary to ensure equal participation for all
- Increasing the number of women in astronomy will improve the professional environment and improving the environment will increase the number of women



Women astronomers working at the Harvard College Observatory, 1925.

"The fun part of my job is trying to recreate the personalities of the early women astronomers who worked at the Harvard College Observatory. Through the recollections and impressions of people who knew these pioneering women, I can piece together a sense of what each was like as a real person."

—*Barbara Welther, science historian*

Welther's expertise centers on the history of astronomy in Europe and the United States during the 19th and 20th centuries, with a special emphasis on women's contributions to astronomy. She does much of her research in archives, historical and genealogical societies, and observatories. She recently wrote, narrated, and produced "Annie and the Stars of Many Colors," a video for grammar and middle school students that explores the life and work of astronomer Annie Jump Cannon, an astronomer,who worked at the Harvard College Observatory from 1896 to 1941 and received numerous honors for classifying hundreds of thousands of stellar spectra. Prior to pursuing graduate work in the history of science, Welther developed computer programs to plot the historic positions of planets and the brightness cycles of variable stars. Her hobbies include early music and playing in recorder ensembles.

Donna Coletti

[LIBRARIAN]

An unusual, colorful work of art hangs on one wall of the CfA's Wolbach Library. Although it resembles a patchwork quilt, close inspection reveals it is made not from fabric scraps but from small squares cut from the covers of old astronomy journals. The artist, Donna Coletti, is quite familiar with her chosen materials—she's also the head librarian at Wolbach.

The quilt reflects, in a certain sense, the nature of Coletti's job—a mix and match of various tasks. As director, she oversees all the regular library functions, including searching computer databases, ordering books, coordinating interlibrary loans, and answering reference questions. Other, unexpected tasks also crop up. "I never dreamed when I went to library school that I would be fixing photocopy machines and installing computer hardware and software," Coletti says.

The challenge suits her just fine. "I need to have something that's really pushing me and making me think all the time, and that's exactly what this job is," she says. Because Wolbach is actually a merger of two separate libraries (Harvard's and Smithsonian's), Coletti has to juggle different budgets, computer systems, and employee evaluation systems behind the scenes, while maintaining the appearance of a single, unified library to the library's patrons. Wolbach serves over 600 people in Cambridge and is considered one of the world's preeminent astronomy libraries.

Coletti, who has a BA in psychology and a MLIS (Master of Library and Information Science), has always been fascinated by astronomy. During her 9 years here, she's picked up a fair bit of astronomy trivia—one of the job's perks. She also appreciates another advantage: private "star parties," when CfA employees can invite friends and family to view the heavens with telescopes on the observatory's roof.

The day-to-day aspects of her job are also rewarding. For instance, a program Coletti pioneered that employs disabled students has proven beneficial for both the library and the students. The students are from a nearby school for children and young adults who have autism or similar disabilities. People with these types of disabilities tend to be very detail-oriented and like

to organize things. In fact, some can reshelve books with a 99 to 100 percent accuracy rate—better than some university undergraduates who have worked in the library. The students also transliterate Russian titles into English, photocopy articles, organize the unbound journals, straighten and dust the shelves, and empty recycling boxes, among other things. "It's like having a team of utility infielders to do all the things we don't have time for," says Coletti.

One of the projects Coletti now has more time to pursue is proposal writing. She constantly seeks funding to preserve and restore some of the library's collection of fragile, aging, historic books.

One task she has no plans to pursue, however, is one that's occasionally requested from people who call from outside the CfA. "They want to know if we can do their astrological charts!" laughs Coletti.✦

Kathryn Flanagan

[Instrument Developer]

When Kathy Flanagan was growing up, it was her brother, not she, who took apart the family toaster. "I was kind of scared of it," admits Flanagan, whose early reluctance to tinker with mechanical things actually motivated her to pursue the unusual combination of physics and civil engineering when she got to college.

She figured it made sense to study things she didn't understand. "Education," she stresses, "is for learning what you don't know, not for sticking with something you think you know."

Today, she's still pushing toward the unknown—and working on projects vastly more complex than repairing toasters. Flanagan designs and tests instrumentation for AXAF, the Advanced X-ray Astrophysics Facility, a space telescope planned to study the emission of x rays from objects such as neutron stars, black holes, and supernova remnants.

The CfA's High Energy Astrophysics Division, where Flanagan works, is developing one of AXAF's main instruments, a multi-million-dollar high-resolution imaging camera. She's part of a team of scientists responsible for an intricate feat of engineering—the design and calibration of the camera's detector. Capturing x rays is much trickier than collecting visible light because the rays, which normally pass right through conventional mirrors, must be focused by deflection at very shallow—almost grazing—angles, explains Flanagan, and then collected and enhanced to create an image. The calibration will involve projecting x rays down a 1/4-mile-long vacuum tube to be focused by special cylindrical mirrors onto the detector.

Flanagan's somewhat unconventional education and job experiences prepared her well for the challenges of her career. With a father who was a career military officer, the family moved frequently, so Flanagan went to three different high schools in three different states. During her senior year, guidance counselors tried to steer her away from physics. "They'd say things like, 'Pharmacy is a good scientific field for women'," says Flanagan.

Undaunted, she pursued her original interest at MIT, earning her bachelor's degree in1976. At the time, women made up less than 10 percent of the student body, a situation that left her feeling somewhat isolated. "I'd be one of two women in a lecture hall of 400 students," recalls Flanagan. "You tend not to ask questions, because you don't want to draw attention to yourself."

Nonetheless, her MIT experience had distinct benefits, with its strong focus on problem-solving. "The emphasis was on how you learn, not what you learn," says Flanagan.

It was also at MIT that Flanagan got hooked on x-ray astronomy instrumentation. For her undergraduate thesis, she worked on an imaging device that flew on the Einstein X-ray Observatory—a predecessor to AXAF. When she returned to MIT in 1984, she wrote her Ph.D. thesis on the remains of an exploded star known as Puppis A—using data collected with the very instrument she helped build.

In between, Flanagan volunteered for the Peace Corps, where she taught math and physics in the war-torn Republic of Zaire. Not only did she teach all the classes in French (which she learned in a 7-week crash course), she sometimes had to compete with the noise of bombings and gunfire.

"To this day," says Flanagan, "whenever I have stage fright before a talk, I remind myself this really isn't so bad—I've lived through a war!"✦

"Young people, especially young women, often ask me for advice. Here it is: Do not undertake a scientific career in quest of fame or money... Your reward will be the widening of the horizon as you climb. And if you achieve that reward you will ask no other."

—*from* The Dyer's Hand, *the autobiography of astronomer Cecelia Payne-Gaposchkin, 1900-1979*

The first person to receive a Ph D. in astronomy from the Harvard College Observatory, Payne-Gaposchkin also became the first woman to head the university's astronomy department. Her pioneering work on variable stars illuminated our understanding of how and why such stars change their brightness, and led to insights about the structure of galaxies, including our own Milky Way. She also made significant contributions about the nature of exploding stars, or novas. Payne-Gaposchkin authored numerous books, including several with fellow astronomer and husband Sergei Gaposchkin. A mother of three, she told a reporter in 1939 that "a career and homemaking and motherhood may be thoroughly compatible, through the exercise of common sense and making of intelligent adjustments."

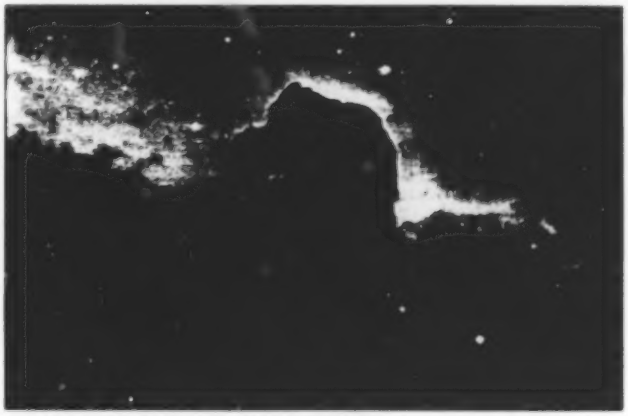
Why Astronomy?

Imagine being high atop a remote mountain on a clear, dark night, with millions of stars glittering overhead. You are inside the observatory, sitting at the controls of a large, powerful telescope. Gradually, a fuzzy patch of light, a distant quasar, appears on the computer screen in front of you. The light you are seeing from that quasar traveled through space for 10 *billion* years before hitting the telescope's detector. In spite of that mind-boggling distance, you can nonetheless decipher many clues about the nature of that quasar. For example, using special instruments that attach to the telescope, you can measure how fast the quasar is moving away from us—a value that helps astrophysicists determine the age and size of the universe.

By observing supernovas—the final, cataclysmic explosions of dying stars—you can learn how stars make heavy elements like iron, silicon, and sulfur. Those, and all the other known elements here on Earth, originated in the stars. Or, you might study how stars are born from vast dusty clouds in our galaxy.

Learning more about the stars helps us to better understand our own star, the Sun. The same is true for the other planets and small bodies of our solar system: Our knowledge about these objects enhances our understanding of the Earth.

Those are just a few of the reasons that people study the heavens. These formal studies are categorized into two broad areas: astronomy, which is the study of all the objects outside the Earth, including the Sun and its other planets, other stars, galaxies, and the universe itself; and astrophysics, which is the application of the laws of physics to help explain the nature of those objects observed by astronomers. (For definitions of other terms, see the *Glossary*.)



The Horsehead Nebula in Orion.

Marquita Jackson-Minot

[Education Specialist]

Rubber balls, paper towel tubes, and plastic bottles filled with blue water surround Marquita Jackson-Minot in her office at the CfA's Science Education Department. These items, plus other cheap and readily available materials, are the mainstays of an innovative new curriculum program designed to teach elementary school students basic concepts in astronomy, she explains.

The tinted water, for example, is poured into a clear plastic cup with a pinhole in the bottom so it drips into another cup, thus producing a water clock. That's just one of the activities used to demonstrate the passage of time—as well as to introduce a simple principle of physics.

"What we're doing is creating and testing discovery-based activities that give real hands-on experience with science," says Jackson-Minot, a 13-year teaching veteran who now works on Project ARIES (Astronomy Resources for Intercurricular Elementary Science).

The goal of ARIES is to make science education more interesting and exciting, using activities based on themes such as "Time," " Light and Color," and "Beginning Astronomy." The modules are developed and evaluated in part by elementary school teachers during summer institutes at the CfA.

In fact, that's how Jackson-Minot first learned about it. As a teacher for gifted and talented 4th and 5th graders at a Boston public school, she often attended summer workshops to brush up on her skills. The ARIES philosophy jibed well with her own—to rely less on textbooks and rote memorization in the classroom.

A New York City native, Jackson-Minot went to Boston University, where she received a degree in elementary education with a minor in biology. She pursued further studies in both subjects for a Master's Degree at Cambridge College, where she wrote her thesis on "Teaching the Systems of the Human Body in an Interactive and Integrated Way." That "interactive way" included having students study chicken legs and wings from the grocery store to learn about muscles, bones, and cartilage.

Astronomy also lends itself to interactive projects, as Jackson-Minot learned at an ARIES workshop in 1992. The following year, the program director asked her to return full-time as a project co-developer. She now field tests each module activity herself, then incorporates feedback from other teachers, while drawing on her own classroom experience, to suggest revisions and improvements.

For example, the "Time" module has students observe, record, and eventually explain in a journal how shadows change with the Sun's position throughout the day. Once they understand how shadows move, explains Jackson-Minot, they can understand how sundials work—the next activity in the module.

Kids also write in their journals about what time means to them, and ponder the reasons for tracking time. "We talk about how the ancient Egyptians watched to see on which day the star Sirius rose just before the Sun at dawn, because that annual event meant the Nile would soon be flooding, and that it was time to plant their fields," says Jackson-Minot. In that way, the astronomy activities are linked to the rest of the student's curriculum, like language, art, history, and geography.

Though she enjoys working on the modules, the best part of her job is visiting classrooms, says Jackson-Minot, who also makes time to go on field trips with her young son's class. "It's really fun watching the kids respond to science concepts," she says. ✦

"Getting people excited about astronomy is a great way to get them interested in exploring their own ideas about science."

—Kimberly Dow, astrophysicist

As Education Coordinator for the High Energy Astrophysics Division, Dow says that encouraging students to pursue scientific careers is one of the most satisfying parts of her job. She directs the Summer Intern Program for college undergraduates, which encourages the participation of women and minorities. Prior to her graduate work at the University of Arizona, she did internships at the United Kingdom Infrared Telescope Facility on Mauna Kea, Hawaii, where she made infrared observations of the galactic center, and at NASA's Johnson Space Center in Houston,where she studied the space debris environment around the Space Station. Now, she researches x-ray observations of clusters of galaxies, in addition to devising new ways to promote awareness and interest in astronomy. In her free time, Dow, who's also a pilot, enjoys flying friends around the New England countryside.

• High School

In high school, it's a good idea to take as much math and physics as possible. Even if you don't pursue a Ph.D. in astrophysics, basic knowledge of those fundamental subjects is helpful and relevant for a number of different careers. Such courses will also provide you with a solid background to make more informed decisions about the day-to-day issues that confront us in our increasingly technologically based world.

What if your high school doesn't offer calculus, or advanced placement physics? Or, what if you didn't realize until later that you were interested in science, and you didn't take math and physics in high school? Consider taking summer classes at a local community college or university.

• College/University

Selecting a college can be somewhat overwhelming, because of the many different institutions to choose from. Ultimately, the decision depends on your own sense of what's important to you. Small, private colleges have the advantage of smaller classes and, often, a more personal environment. Larger universities, however, are more likely to have cutting-edge research facilities and may provide greater research opportunities for undergraduates. State universities generally have lower tuition costs. Some women find that all-female colleges provide an environment that offers leadership opportunities and builds self-esteem, others prefer to face the challenge of a coeducational institution.

Universities located near major astronomical observatories, where dry, sunny weather prevails much of the year, such as the University of Arizona in Tucson and the University of California at Los Angeles, are good choices for students interested in astronomy and astrophysics majors. However, colleges and universities all over the country offer majors in those subjects, and most institutions offer a physics degree, which also provides an essential background for graduate work in astrophysics.

Your best bet is to visit as many schools as possible, so you can talk to students and professors to get a sense of each place. If you want to pursue graduate work in astrophysics, plan to take two years of undergraduate

courses in physics. Don't forget to request letters of recommendation from your professors to be kept in school files, even if you don't plan to pursue graduate work. You may need them if you change your mind later.

• Graduate School

While some aspiring astronomers and astrophysicists know what particular area of research they'd like to pursue, many do not. Some students select their school in order to work with a particular professor whose work they admire. Often, however, students don't choose an advisor until after their first semester in graduate school. Selecting an advisor is one of the most important decisions in your career, because you'll work closely with that person for several years and rely on him or her for support, advice, and, ultimately, job recommendations. The best advisors tend to be not only brilliant researchers but also fine teachers, successful at obtaining funding, and influential in their fields. Make an effort to speak with several of the professor's past and current students to get a sense of what he or she is like to work with so you can make an informed decision.

Most graduate students in science don't have to pay tuition to attend universities, and most also receive small stipends for living expenses. Students may get funding in the form of a fellowship, that is, a teaching or research assistantship. Fellowships are like scholarships in that the money is essentially a gift, but they usually require that you be a full-time student and maintain a "B" average. Teaching assistants help professors with teaching duties, like grading homework, teaching sections, or proctoring exams. Research assistants do research with their advisors, usually on a topic that 's directly related to their thesis.

Informal Education: Helping Yourself

Aside from formal education, there are many other ways to learn more about astronomy. Reading astronomy magazines and books (see *Appendix*) is an easy way to become acquainted with the general field. But you can also join a local astronomy club to get some actual hands-on experience with small telescopes. In many cities throughout the country, groups of amateur astronomers meet regularly to do observations using small portable telescopes, some of which are built by the members themselves. Also, many colleges and universities have small observatories that are open to the public.

Volunteering at a local science museum or planetarium is another way to get involved in astronomy, especially its educational and outreach functions. Finally, there are several internships available for high school and college students that provide unique opportunities to experience astronomy. (See *Appendix*.)

Honore Daumier print, 1858. Museum of Fine Arts, Boston.

Facing Challenges

Careers in science are challenging for everyone—regardless of gender, race, or any other attribute. Scientists must complete years of rigorous academic training, keep up with a barrage of new research findings and technologies, and compete for ever-scarcer funding resources. But these challenges are part of what makes science a stimulating and exciting career.

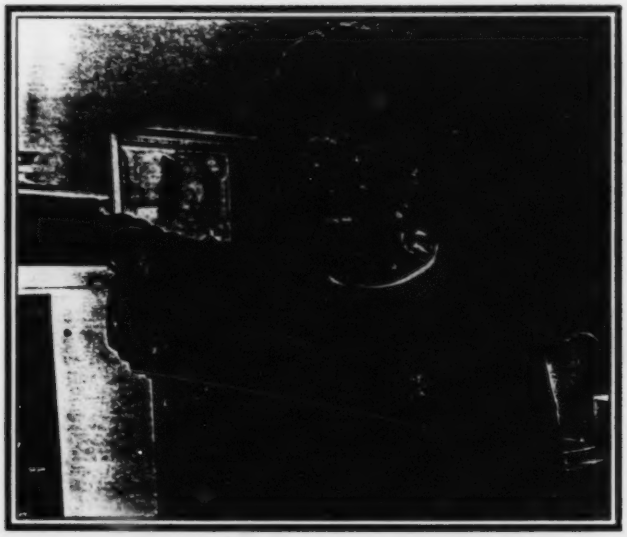
Female scientists, however, must often deal with problems that affect their male counterparts far less frequently. Physics, astronomy, astrophysics, geology and engineering have traditionally been—and still are—largely male-dominated fields. As a minority group, women in these fields do confront discrimination. Although overt sexism is becoming less common, subtle forms of unequal treatment toward women persist. For example, studies have shown that male students tend to receive more attention in the classroom, and are more likely to be encouraged to take math and science classes. In the college years and beyond, the "old-boy network" tends to promote males and exclude females.

What can you do about it? First, keep in mind that discriminatory behavior may be habit, and not done intentionally. Try not to take it personally, and remember that difficulties and disappointments—which

(to page 12)

Alyssa Goodman

[ASTROPHYSICIST]



High atop Mauna Kea on the big island of Hawaii, the thin, dry air makes for sharp astronomical imaging. The low oxygen levels at the mountain's 13,000-foot summit can also sometimes lead to fuzzy thinking, notes Alyssa Goodman, an astrophysicist with the CfA's Radio and Geoastronomy Division.

Nonetheless, it was on Mauna Kea where Goodman had a flash of insight—what scientists sometimes refer to as the "Aha!" moment. Goodman, who is also an assistant professor of astronomy at Harvard, studies dark clouds—the vast, dusty regions in space where starbirth occurs. For over 40 years, scientists have used background starlight polarimetry to map magnetic fields in interstellar clouds. Such measurements, done at infrared wavelengths, were thought to reveal the nature of a very dense cloud's magnetic field—which, in turn, determines the ultimate fate of the cloud. But, late one night on Mauna Kea, after tapping some data into her laptop computer, Goodman suddenly realized that the technique was wrong. The observations she and colleagues had just made showed that the magnetic fields in dense, dark clouds don't alter the background starlight—meaning that the polarimetry was useless.

At first, the discovery was met with some doubt. However, after the team announced their findings, Goodman was invited to give lectures at research centers around the country. "People tended to be a bit skeptical. Once they saw the data, it was irrefutable," she says.

Organizing data and preparing lectures may be solitary pursuits, but collaboration is an equally important part of research. "In this field, you sometimes get to a point where you don't totally understand what you're doing and you either have to pretend that you do understand, or seek help by cooperating with others," says Goodman. "This is how science really gets done!"

In fact, who you work with can be a crucial link to a successful scientific career. Goodman, who has a BS in physics from MIT, received her master's and doctorate in physics from Harvard, working with Philip Myers, another star-formation expert at the CfA.

"The summer before graduate school, I wrote letters to people saying their research sounded intriguing—the topics ranged from magnetic fields to quasars. Phil sounded the most interesting and enthused, so I asked to be his research assistant, and then I became his graduate student."

Although she's happy with her current job ("The best part is that I'm never bored"), she says she once seriously considered studying anthropology instead of physics, and finds many other fields equally fascinating.

"When I was a kid I wanted to be Jacques Cousteau," says Goodman, who almost went on an underwater archeological dig in the Caribbean the summer before her senior year in college. Instead of paying to go on the dig, she accepted a paid internship at the NASA-Goddard Institute for Space Studies. Sometimes financial considerations take precedence, she admits.

And, although Goodman's discovery that night on Mauna Kea challenged the astronomical establishment, she doesn't feel that her gender has presented any particular challenges to the progress of her career.

"People say to me, 'Oh, you must have overcome such discrimination to get here,' says Goodman, who is one of three female professors in Harvard's 21-faculty-member Astronomy Department. "The truth is, nobody ever told me I wasn't supposed to be doing any of the things I was doing."✦

Carolyn Stern Grant

[COMPUTER SPECIALIST]

Although many people envision astronomers peering through telescopes on lonely mountain peaks, most actually spend much more time in their offices, gazing at computer screens.

That's precisely why computer programmers like Carolyn Stern Grant are a vital part of the day-to-day functioning of institutions like the CfA.

Essentially, Grant's job is to help scientists easily access the vast amounts of astronomical information now available via computer databases. Abstracts of published scientific papers, news of new discoveries, analyses of space observations, as well as a dazzling array of colorful astronomical images—from planets to pulsars—can be found on computer networks. The information, gleaned from research institutions around the world, enables researchers to compare their results with others, or helps them prepare for their own observations.

Grant devotes most of her time to working on one means for distributing such information—a software program called the Astronomical Data System (ADS). Developed and operated by NASA, the program was designed primarily to make data from NASA space missions available to astronomers. A consortium of six institutions around the country, including the CfA, maintains and updates the program.

One of Grant's tasks was to develop a "graphical user interface" for ADS. This means she wrote programs allowing users to simply point and click on descriptive images that would guide them through the program. Although she'd taken computer courses in college, Grant learned most of her skills on the job. The ADS project was a good one to start with "because I didn't have to write a huge, complicated program—just one part of it," she says.

She's also found the work environment to be friendly and supportive. In the CfA's High Energy Astrophysics Division where Grant works, about half the computer programmers are women, even though the division's scientific staff (like the rest of the CfA) is mostly men. Grant offers a possible explanation for the discrepancy: "Maybe there are more women doing this type of programming because it's a fairly new field—there's no previous history of women being excluded."

Grant, who received a BA in the history of science from Harvard University in 1986, started working at the CfA as a research assistant while still an undergraduate. Her first major project, done with CfA astrophysicists Christine Jones Forman and Bill Forman, was to help create "Colors of the Universe," a set of 175 slides that provides multispectral views of astronomical objects—from an infrared photo of Orion to x-ray images of quasars.

She and her husband Paul, who also works on computers at the CfA, live with three cats in a tranquil, wooded suburb of Boston. Grant is also an accomplished clarinet player who plays in a woodwind quintet.✦

happen to everyone—may be a result of the system, not you. Seek out mentors, both female and male, who will support and encourage your work. Initiate contact by introducing yourself, either in person or by a letter. Ask questions or comment on a recent article the person has written, or ask for comments on your own work. Always be appreciative, and acknowledge all the help you're given. See if you can apprentice yourself as a research or teaching assistant. Finally, team up with other women who share your interests and career goals.

Another question that concerns some young women who are considering a science career is whether or not they'll also be able to raise a family. Women who do both acknowledge that it is challenging. But many assert that science isn't any more difficult than other fields in terms of having children. Even though scientists often work long hours, they don't always have to adhere to a strict, 9 to 5 schedule, and can be more flexible in terms of their daily scheduling.

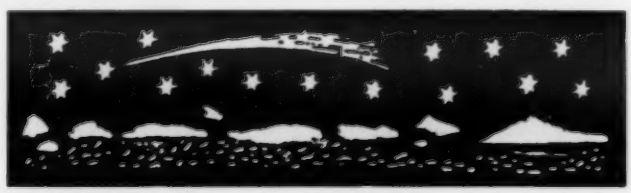
Having a supportive spouse or partner who shares the household responsibilities makes it much easier to juggle the demands of work and family. Also, daycare is much more widely accepted and available than it was 20 years ago. In fact, there is on-site daycare available at the biannual meetings of the American Astronomical Society, the largest astronomy conference in the United States.

Astrophysicist Rosanne Di Stefano talking with high school students after presenting a CfA public lecture.

"I feel very strongly that children and daycare should be discussed in the workplace. Everybody needs to realize that it's both a man's and a woman's responsibility to deal with family issues."

—Kate Kirby, astrophysicist

To Kirby, a mother of four, the key to successfully combining career and family is having a supportive, involved spouse who respects and understands her commitment to her work. As associate director of the CfA's Atomic and Molecular Physics Division, she oversees the division's research projects and serves on a number of scientific committees and professional societies throughout the U.S. In her research, she uses mathematical analysis and sophisticated computer programs to study interactions of atoms, molecules, and radiation in the Earth's upper atmosphere and the interstellar medium. She is particularly interested in the manifestations of global change in the Earth's atmosphere. Outside of work, she's often off at her children's ice hockey and soccer games, dance recitals, or piano lessons. She, her husband, and their children are also all avid downhill skiers.



Tania Ruiz

[ASTRONOMER]

During h · freshman orientation week at Harvard, Tania Ruiz walked over to the CfA and wandered around until she found the secretary of the Astronomy Department. "I asked if there were any jobs I could do, and told her I'd work for free, just for the experience," says Ruiz, who graduated from Harvard in 1994.

She was following advice from her mother, who'd always encouraged her to "go out and get your face known." That counsel, combined with Ruiz' enthusiasm and dedication, served her well. As a freshman, Ruiz not only became a regular volunteer at the CfA's monthly Observatory Nights for the public, she was also hired to work in the Radio and Geoastronomy Division, and as a teaching assistant for the introductory astronomy course offered by Harvard's Extension School. After graduation, she landed a research position in the CfA's High Energy Astrophysics Division.

At the public nights, Ruiz often runs a 9-inch telescope on the CfA's roof, showing people Saturn's rings, lunar craters, or distant galaxies. She especially likes introducing the wonders of the night sky to the uninitiated. "When I see someone look through a telescope the first time, it reminds me of why I got into this field," she says.

Her first peek through a telescope was on a playground, in third grade. That experience, along with seeing "Star Wars" when she was 6 ("I loved that movie!"), kindled her early interest in astronomy.

Growing up in New Jersey, Ruiz was in a talented and gifted program at her public school, where she was lucky to have "very good teachers." After moving to Maryland when she was 16, Ruiz joined a local astronomy club. "Most of the people were much older, mainly retired men," she says.

During her senior year in high school, Ruiz did an internship at a local planetarium, where she built a decametric radio telescope, a special type of telescope designed to listen to emissions from Jupiter. Decametric refers to the very long (tens of meters) radio wavelengths "heard" by the telescope.

The telescope—which she calls her "interstellar basketball hoop"—consisted of a 66-inch-long, circular, copper-wire antenna, suspended over a chicken-wire-and-lumber frame. Jupiter's "voice," which could be heard on a shortwave radio connected to the telescope, sounded like waves crashing on the beach, according to Ruiz. The sounds are thought to be echoes of charged particles streaming into the Jovian atmosphere, caused by disturbances in the planet's magnetosphere.

The project won Ruiz top honors at her county science fair and earned her a trip to the1989 International Science Fair in Tulsa, Oklahoma, where she picked up a computer as a first place prize from the US Army, as well as a visit to Johnson Space Flight Center in Houston, Texas, from NASA.

In addition to getting involved in clubs, finding volunteer opportunities, and seeking out mentors, Ruiz has the following advice for aspiring astronomers: "In high school, take good notes and save them—you'll use them in college for review. In college, join study groups, so you can do your problem sets with other people. Don't be afraid to ask questions and to talk to your teachers after class."✦

Ursula Marvin

[GEOLOGIST]

She's slogged through lush, green jungles in South America and snowmobiled across the barren, icy wastes of Antarctica. For CfA geologist Ursula Marvin, such adventures are highlights of a long, varied career that has ranged from studying our planet to analyzing tiny chunks of our solar system: Moon rocks and meteorites.

"These extraterrestrial samples can tell us much about the nature of our own planet and the history of the solar system," says Marvin, who specializes in the mineralogy of lunar samples and meteorites. Composed of stone, iron, or a mixture of the two, most meteorites are thought to be fragments of collided asteroids that have fallen on Earth from space.

Before joining the Smithsonian in 1961, she spent several years working for the Union Carbide Ore Company. She and her geologist husband Tom worked together, prospecting for manganese oxide in the jungles of Brazil and the highlands of Angola.

Though they lived in tents for five months at a time, Marvin found that "roughing it" was easy. To her, the job was a great way to pursue what she calls "a natural love affair with geology." Growing up in rural Vermont, she had always enjoyed the outdoors. She majored in history at Tufts College, but, after discovering geology in her junior year, she went on to pursue a master's in the field from Harvard-Radcliffe in 1946.

She worked at the University of Chicago, Tufts, and Harvard, as well as Union Carbide, before returning to Harvard for her Ph.D. in 1969, the same year that Apollo astronauts brought back a precious bounty—the first rocks from the Moon. Marvin and her colleagues were among a select group of scientists who received samples from that and the five subsequent missions.

In a sample from the Apollo 15 mission, Marvin discovered the first example from the Moon of a mineral called cordierite. This magnesium-rich mineral is especially interesting because it apparently formed under pressure, deep within the Moon's crust. A blast from a meteorite impact, says Marvin, may have brought it to the surface.

Although the Moon bears evidence of numerous meteorite hits, weathering processes on Earth have buried or removed most large meteorite craters from the past. However, a host of smaller meteorites continue to rain down on our planet, each bringing possible new clues to solar system history. One of the best places to hunt for them is in Antarctica, where these rocky treasures can be preserved by the ice and then pushed to the surface after hundreds of thousands of years in cold storage.

Following an initial, chance discovery of nine meteorites by a Japanese team in 1969, American meteorite hunters set out for the icy continent. Marvin went on two collecting expeditions during the next decade. Clad in puffy down parkas, she and colleagues traversed broad fields of bluish-white ice on snowmobiles, under the brilliant Antarctic summer sun, and collected dozens of specimens. In recognition of Marvin's efforts, a *nunatak*—a small mountain completely surrounded by a glacier—was named in her honor. Marvin Nunatak rises 2090 meters above the Cassidy Glacier, west of the Quartermain Mountains in Victoria Land, Antarctica. Appropriately enough, she also has a namesake in the heavens, an asteroid orbiting the Sun millions of kilometers from Earth. Perhaps Minor Planet Marvin will one day spawn some meteorites for future planetary scientists to find on Earth.✦

APPENDIX

MAGAZINES

*Sky and Telescope**
Sky Publishing Corp.
49 Bay State Road
Cambridge, MA 02138
(617) 864-6117

Astronomy
Kalmbach Publishing Co.
21027 Crossroads Circle
P.O. Box 1612
Waukesha, WI 53187
1 (800) 533-6644

Two of the most popular astronomy magazines, geared toward amateur astronomers, that feature reports of recent discoveries, advice on observing, astrophotography, and more. Both are $27.00/year by mail subscriptions; also available on news stands and at most libraries.

*The September issue contains an "Astronomical Directory" Supplement with comprehensive listings of astronomy clubs, computer bulletin boards, telephone hotlines, observatories, museums, and planetariums.

Mercury
Astronomical Society of the Pacific
390 Ashton Ave.
San Francisco, CA 94122
(415) 337-1100

A bimonthly, non-technical magazine of astronomy for students, teachers, and amateur astronomers. $35.00/year.

Earth in Space
American Geophysical Union
2000 Florida Ave., NW
Washington, DC 20009
1 (800) 966-2481

A magazine on current geological events and research for high school students. $12/year for 9 issues (September-May).

StarDate Magazine
RLM 15.308
University of Texas, Austin
Austin, TX 78712
1 (800) 782-7328

A popular astronomy magazine, geared toward general audiences, featuring star maps and observing information. $15.00/year.

BOOKS

Opening the Space Frontier by Ray Spanenberg and Diane Moser. New York: Facts on File, 1989.

Origins: The Lives and Worlds of Modern Cosmologists by Alan Lightman and Roberta Brawer. Cambridge: Harvard University Press, 1990

Through a Universe Darkly: A Cosmic Tale of Ancient Ethers, Dark Matter, and the Fate of the Universe by Marcia Bartusiak. New York: Harper Collins, 1993.

Turn Left at Orion: A Hundred Night Sky Objects to See in a Small Telescope and How to Find Them by Guy Consolmagno and Daniel Michael Davis. New York: Cambridge University Press, 1989.

Universe, 3rd Edition, by William J. Kaufmann. New York: W. H. Freeman, 1991

Women at Work: A Meeting on the Status of Women in Astronomy (Proceedings of a workshop held at the Space Telescope Science Institute) by C. Megan Urry *et al.*, Baltimore: STScI, 1992. Copies of the Charter and/or the conference proceedings are available from the editors at STScI, 3700 San Martin Drive, Baltimore, MD 21218; or by e-mail: cmu@stsci.edu.

(For more comprehensive lists, write to the CfA Publications Department, which distributes free reading lists on *Skywatching*, *Astronomical People and Places*, *The Universe and its Origins*, and *Exploring Space*. The Astronomical Society of the Pacific also publishes *Women in Astronomy: A Bibliography*, which includes books as well as magazine articles)

VIDEOS

So Many Galaxies, So Little Time
(Junior high to adult)

A 40-minute video about a team scientists led by CfA astrophysicists Margaret Geller and John Huchra who measure the redshifts of thousands of galaxies in an effort to map the large-scale structure of the universe. $39.95. Available from the Astronomical Society of the Pacific, (415) 337-2624.

Annie and the Stars of Many Colors
(4th grade to middle school)

A 25-minute video that explores the life and work of astronomer Annie Jump Cannon. $39.95. Available from the CfA Publications Department, (617) 495-7461

ORGANIZATIONS

American Association of Variable Star Observers
25 Birch Street
Cambridge, MA 02138
(617) 354-0484
aavso@cfa.harvard.edu

Devoted to serious and systematic research on variable stars; publishes a journal, newsletter, and research reports.

American Association of University Women
111 16th St. NW
Washington, DC 20036
(202) 785-7700

Committed to enhancing the equality and education of girls and women.

American Astronomical Society
AAS Executive Office
1630 Connecticut Avenue, NW
Suite 200
Washington, DC 20009
(202) 328-2010
aas@blackhole.aas.org

The major organization of professional astronomers in the United States, Canada, and Mexico; promotes the advancement of astronomy and closely related branches of science.

American Physical Society
One Physics Ellipse
College Park, MD 20740-3844
(301) 209-3200

A national organization for professional physicists. The APS has a Committee on the Status of Women in Physics, which offers a booklet, "Physics in Your Future," and produces a quarterly newsletter.

Association for Women in Science
1522 K Street NW, Suite 820
Washington, DC 20005
(202) 408-0742

Works to improve educational, employment, and advancement opportunities for women and girls in science at all levels.

Association of Women Geoscientists
Macalester College
Geology Department
1600 Grand Avenue
St. Paul, MN 55105-1899
(612) 696-6448

Seeks to enhance the quality and level of participation of women in the geosciences.

Association for Women in Mathematics
4114 Computer and Space Sciences Building
University of Maryland
College Park, MD 20742-2461
(301) 405-7892
awm@math.umd.edu

Promotes equal opportunity and equal treatment of women in the mathematical sciences.

Astronomical Society of the Pacific
390 Ashton Ave.
San Francisco, CA 94112
(415) 337-1100

Works to increase public understanding and appreciation of astronomy; publishes an annual catalog of books, videos, posters, slides, and other astronomy-related educational materials.

National Aeronautics and Space Administration
NASA Headquarters
Office of Public Affairs
Third and E Streets, SW
Washington, DC 20546
(202) 358-0000

Conducts aeronautical and space activities, creates a national science program using aeronautical and space vehicles, and informs the public about these activities.

National Space Society
922 Pennsylvania Ave. SE
Washington, DC 20003
(202) 543-1900

Promotes the advancement of humankind's ability to live and work in space.

Planetary Society
53 N. Catalina Ave.
Pasadena, CA 90025
(818) 793-5100

Devoted to encouraging, supporting, and participating in the exploration of the solar system, the search for planets around other stars, and the search for extraterrestrial life and intelligence.

Women in Engineering Program Advocates Network
Purdue University
1284 CIVL Building, Room G293
West Lafayette, IN 47907-1284
(317) 494-5387

Focuses on increasing the numbers of women engineers by initiating and expanding programs for women at the precollege, undergraduate, and graduate levels.

INTERNSHIPS/ RELATED PROGRAMS

Directory of Student Science Training Programs
Science Service
1719 N Street, NW
Washington, DC 20036
(202) 785-2255

A booklet listing science internships throughout the country for high school students. $3.00/copy.

Young Scholars Projects
National Science Foundation
4201 Wilson Blvd.
Arlington, VA 22230
(703) 306-1616

Offers dozens of local and national programs around the country for 7th to 12th grade students.

Summer Intern Program
Harvard-Smithsonian Center for Astrophysics
60 Garden St., MS-83
Cambridge, MA 02138
(617) 496-7586
intern@cfa.harvard.edu

This program is one of about a dozen summer internships in astronomy sponsored by the National Science Foundation Research Experiences For Undergraduates program. For information on other sites, located at universities and observatories throughout the country, contact the NSF at 4201 Wilson Blvd., Arlington, VA 22230, (703) 306-1819.

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Glossary

asteroid A nonluminous chunk of rock smaller than a planet but larger than a meteoroid, in orbit around the Sun (also known as a "minor planet").

Advanced X-ray Astrophysics Facility (AXAF) NASA's planned orbiting observatory to study x-radiation from space, scheduled for launch in 1998.

atom A submicroscopic building block of much of matter, consisting of a positively charged nucleus and one or more negatively charged electrons in orbit around the nucleus.

black hole A dense, compact object whose gravitational pull is so strong that—within a certain distance of it—nothing can escape, not even light. Black holes are thought to result from the collapse of certain very massive stars at the ends of their lives.

Comet West

comet A small body of icy and dusty matter that orbits the Sun, probably leftover debris from the formation of the solar system. When a comet nears the Sun, some of its material vaporizes, forming a large head of glowing gas, and, often, a tail, millions of miles long.

continental drift The slow motion of huge blocks of Earth's surface, explained in the theory of plate tectonics as an interacting set of shifting regions called plates, and associated with the formation of mountain ranges and earthquakes.

cosmology The study of the birth, evolution, and ultimate destiny of the universe.

dark cloud A region of space between stars with a rich concentration of gas and dust in an irregular but well-defined cloud that obscures the light from stars beyond it.

galaxy A huge assemblage, typically millions to hundreds of millions, of stars. Our galaxy is the Milky Way; our closest neighbor is Andromeda, some 2 million light-years away.

glacier A large body of ice moving slowly down a slope or valley or spreading outward on a land surface.

globular cluster A spherical collection of many thousands, sometimes even millions, of old stars, usually some 10 to 20 light-years in diameter.

element A generic term denoting all the various kinds of atoms; all atoms of the same kind—an element—have identical chemical properties and the same number of protons in each atomic nucleus.

electromagnetic radiation The radiation consisting of waves propagated into space, emitted by all bodies in the universe, and including radio, infrared, optical light, ultraviolet, x rays, and gamma rays.

Hubble Space Telescope (HST) The first large optical telescope launched above the Earth's atmosphere and carrying instruments sensitive to visible and ultraviolet light. The telescope, built by NASA with major contributions from the European Space Agency and launched in 1989, was seriously flawed, but repairs made in 1993 made it the ultimate astronomical instrument.

interstellar medium Gas and dust between the stars.

Jovian Of or relating to the great gas giant planet, Jupiter.

Sombrero Galaxy

A globular cluster

magnetosphere A region of space, usually high above a planet's atmosphere, where charged particles are magnetically deflected and/or trapped.

maser A compact source of highly amplified microwave emission, usually located in a hot, dense region of a gas and dust cloud and detectable only with submillimeter and radio telescopes.

meteor The brief flash of light in the sky from a rock or dust burning up as it falls through Earth's atmosphere, popularly called a "shooting star."

meteorite An interplanetary chunk of rock that has survived the passage through the atmosphere to fall on the Earth.

meteoroid An interplanetary chunk of rock smaller than an asteroid—and the proper term for the object while it is still in space.

mineral Any of various naturally occurring, homogeneous substances, such as coal, salt, or sand, obtained for use by humans, usually from the ground.

molecule A tightly knit group of two or more atoms, bound together by electromagnetic forces among the electrons and nuclei of the atoms.

nebula Intersteller concentrations of dust and gas.

nova A star that in its final moments of life suddenly increases in brightness, temporarily increasing its luminosity by hundreds to thousands of times.

neutron star The compressed remnant of a very massive star that has collapsed in a nova or supernova explosion; made almost entirely of neutrons (subatomic particles with no electric charge). Some neutron stars are known to spin very rapidly and can be detected as "pulsars," rapidly flashing sources of radio or x-ray radiation.

Saturn

planet A rocky and/or gaseous body, generally much cooler and smaller than a star, in orbit around a star. Planets in our solar system "shine" from light reflected from the Sun.

polarimetry A technique for measuring the polarization, or specific radiation patterns, usually aligned in a single direction, of light.

pulsar A celestial object that gives off extremely brief and highly regular pulses of radio waves. (See "neutron star.")

quasar One of a class of very distant (typically billions of light years away), extremely bright, and very small objects. Its name derives from "quasi-stellar radio source."

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since the first of such objects were discovered by radio astronomers.

radiation A form of energy consisting of massless particles called photons that travel at the speed of light, and of which optical light itself is a special kind. (See "electromagnetic spectrum" for other examples.)

red shift The lengthening (or "stretching") toward the red end of the spectrum of light waves coming from a distant cosmic source moving away from us. (If a source of light is moving toward us, the opposite effect—called a "Blue Shift"—takes place.)

satellite A body that orbits around a planet, such as the Moon (a natural satellite) or the Hubble Space Telescope (an artificial satellite), both of which orbit around the Earth.

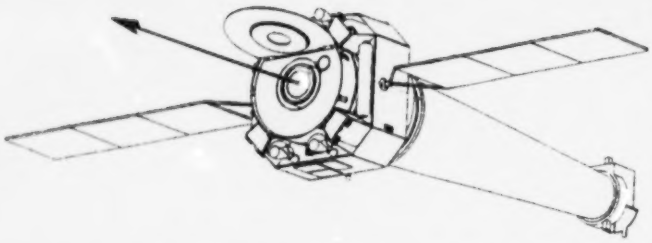
spectroscopy An observational and analysis technique designed to disperse radiation into its component wavelengths in order to study in fine detail the way that matter emits or absorbs radiation.

star A gaseous object held together by its own gravity that shines or has shone because of nuclear reactions in its interior; our Sun is one such star.

supernova The final explosion of a massive star in its death throes, with the resulting release of tremendous amounts of radiation.

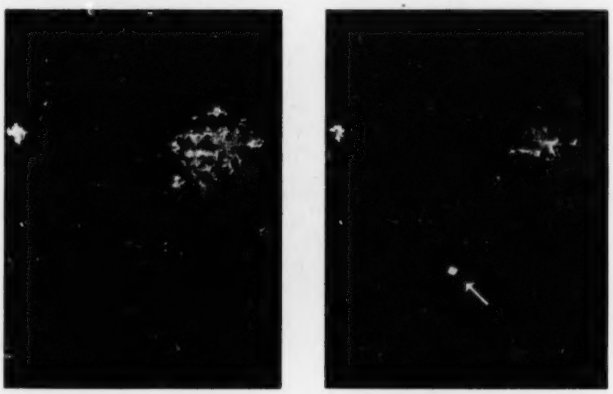
very long baseline interferometry (VLBI) The technique of using simultaneous measurements made with several individual radio telescopes at widely separated locations to create the equivalent of a single telescope hundreds of miles in diameter, and thus capable of extremely high-resolution imaging.

white dwarf An old, dim star, much smaller in size and hotter than the Sun.

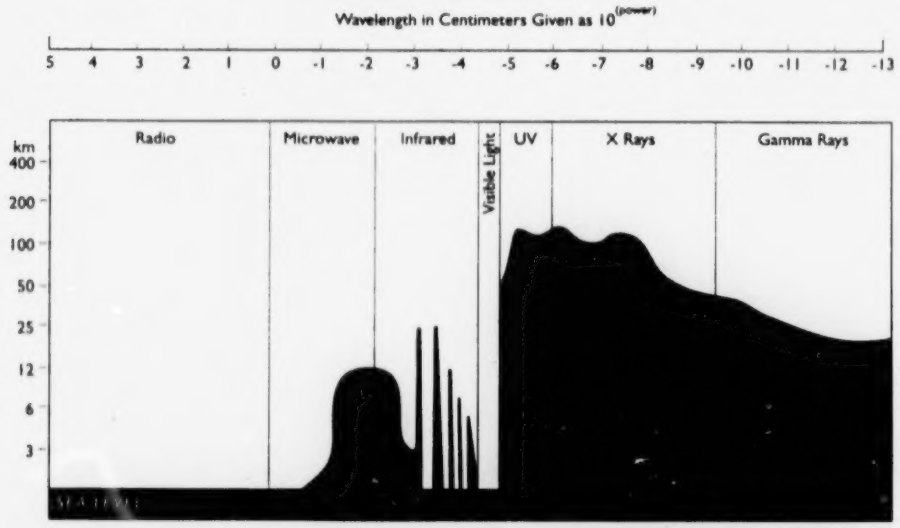


Above: Diagram of the Advanced X-ray Astrophysics Facility (AXAF) (See definition, opposite, and page 7)

Below: Two images of the same region of the sky in the Large Magellanic Cloud (a nearby galaxy), taken before (left) and after the explosion of a massive star, or supernova. Arrow in the right photo points to the supernova, known as SN1987A.



Below: Diagram showing the various wavelengths of the different types of electromagnetic radiation and the distance each type can penetrate through the Earth's atmosphere. For example, radio waves and visible light penetrate all the way to sea level. But most ultraviolet light and x rays are blocked by our atmosphere and can only be detected by instruments carried into space.



SPACE FOR WOMEN

Writer: Julie Corliss

Editor: James Cornell

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Jon Chase, p. 11

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pp. 3 (lower left) and 16 (bottom)

Smithsonion Astrophysical Observatory
pp. 6 (lower right), 12 (upper right), 16 (left and top) and back cover (right)

National Optical Astronomy Observatories
p. 17 (middle) and back cover (top)

Space Telescope Science Institute
Back cover (bottom)

Back Cover
Top: The Orion Nebula
Right: The Multiple Mirror Telescope at SAO's Whipple Observatory
Bottom: Jupiter following impacts by Comet Shoemaker-Levy 9, July 1994

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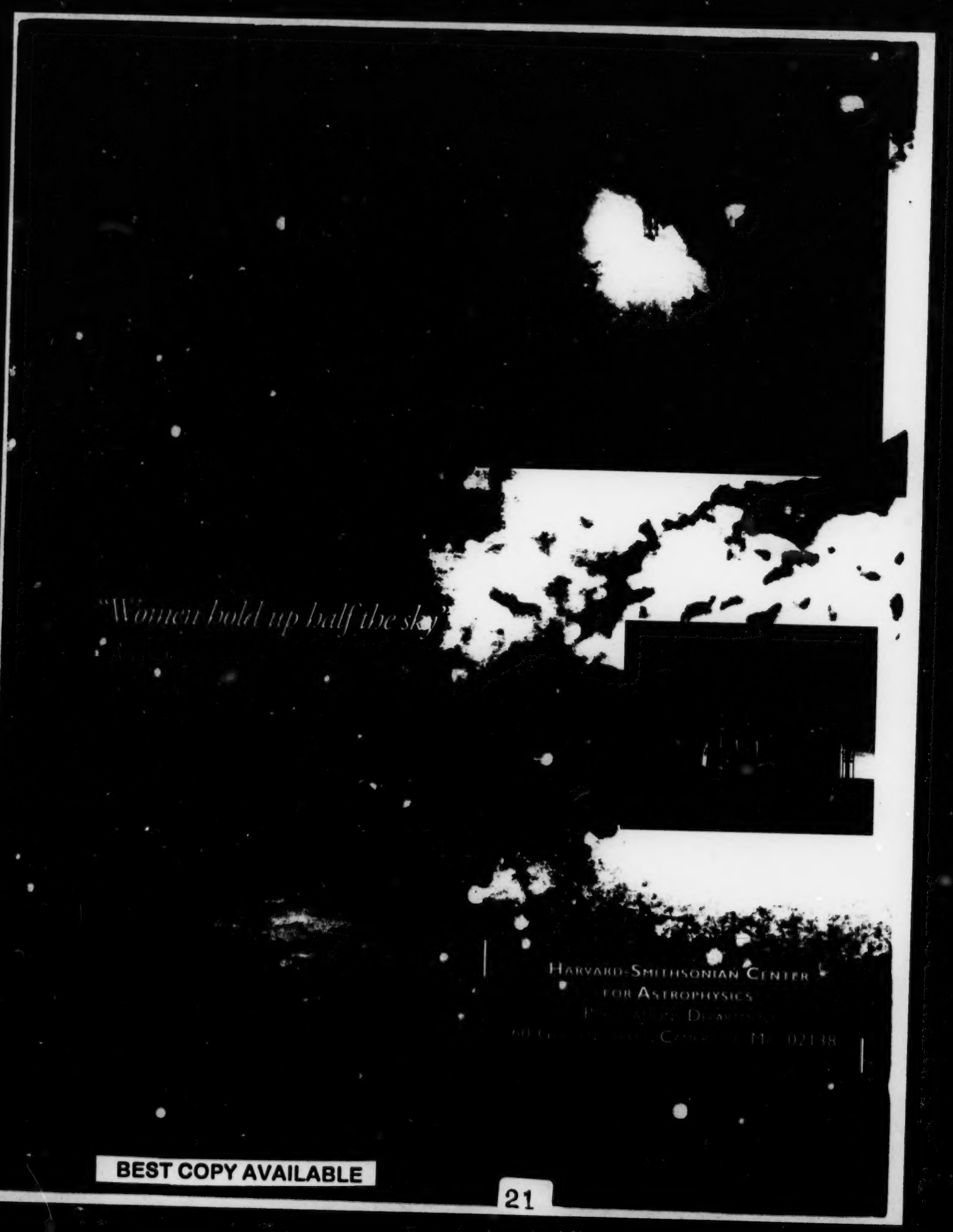

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